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(54) Preemptive roaming in a cellular local area wireless network

(57) A communications network comprising a cellular local area wireless network includes a plurality of access points (5) connected to a house computer (4) and each other, and a plurality of mobile units (2) each mobile unit being arranged for association with an access point. The mobile units are arranged to periodically scan for and identify the most eligible access point for association on the basis of the criteria of best quality signal strength and loading factor. In order to identify when mobile units are being removed from a predetermined area, access points having directional antennae (22) are situated adjacent exit points (21) to detect when mobile units are in a vicinity.

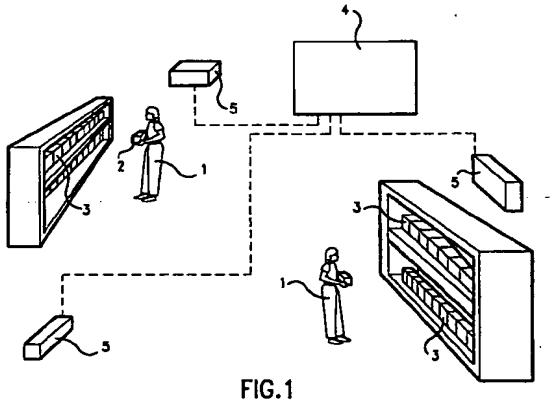

FIG.1

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Description

REFERENCE TO RELATED APPLICATIONS:

This application is a continuation-in-part of application Serial No. 08/044,648, filed April 8, 1993, now U.S. Patent No. _____, which was a continuation-in-part of Serial No. 07/799,172, filed November 27, 1991, now U.S. Patent No. 5,296,842, which was a continuation-in-part of application Serial No. 07/635,859, filed December 28, 1990, now U.S. Patent No. 5,142,550, which was a continuation-in-part of application Serial No. 07/374,452, filed June 29, 1989, now U.S. Patent No. 5,029,183, issued July 2, 1991. This application is related to application Serial No. 08/344,737, filed November 23, 1994 and Serial No. 08/193,069, filed January 18, 1994, now U.S. Patent No. _____.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates generally to preemptive roaming among cells in a cellular network. In particular the invention relates to a local area wireless network including a plurality of mobile units and a plurality of access points.

2. Description of the Related Art

Wireless local area networks (LAN'S) are used in business applications such as inventory, price verification mark-down, portable point of sale, order entry, shipping, receiving and package tracking. Such systems are often proprietary systems wherein the operator carries a mobile unit such as a hand-held computer communicating with a house computer via one of a plurality of access points connected to the house computer and to one another, each access point interacting with the house computer to create a wireless cell.

In order to achieve inter-operability of the various proprietary systems a draft standard IEEE 802.11 has been proposed (the IEEE 802.11 draft specification is available for public inspection).

The draft standard includes features such as 1Mbps and 2Mbps data rates, carrier sense multiple access/collision avoidance (CSMA/CA), a power-save mode for battery-operated mobile stations, seamless roaming in a full cellular network, high throughput operation, diverse antenna systems designed to eliminate "dead spots", and an easy interface to existing network infrastructures.

The term "roaming" relates to the scanning by each mobile unit of all access points to identify and associate with an eligible access point. Roaming between cells provides great flexibility and is particularly advantageous in locations that are difficult to wire, for simple relocation of work stations, and for portable work stations. The IEEE 802.11 protocols supports either direct-sequence or frequency-hopping spread-spectrum systems, as well as infrared communications. Each access point executes a unique hopping pattern across 79 non-overlapping frequencies at a rate of one hop every 100 milliseconds, 66 hopping patterns being specified in the IEEE 802.11 draft standard and being selected to minimise the possibility of interference. Frequency hopping spread-spectrum systems are preferred by the majority of users as they allow increased capacity and decreased interference.

Although the IEEE 802.11 draft specification provides the basic packet types which can enable roaming it does not actually set the roaming algorithm. According to the draft specification the mobile unit determines the access point with which it will associate and the access point must accept the mobile unit unless it is defective or certain alarm conditions exist, such as memory full. There is, however, no suggestion of how, or by what criteria, other than those mentioned above, the mobile unit might select an appropriate access point, or the optimum access point.

US 5,276,680 relates to a communication system including a plurality of portable units and a plurality of controllers wired to a network. Each portable unit polls all of the controllers to establish whether it can associate with any controller and receives a response from any controller having less than a predetermined number of portable units already associated therewith.

SUMMARY OF THE INVENTION

1. Objects of the Invention

It is an object of the present invention to provide a communication system allowing improved selection by a mobile unit of an access point for association.

It is a further object of the present invention to provide a communication system allowing selection by a mobile unit of an access point to provide optimum operation of the system.

It is a further object of the present invention to provide a communication system providing information concerning the physical location of a mobile unit.

It is a further object of the present invention to provide a communication system adapted to prevent mobile units from being taken outside a given physical area.

2. Features of the Invention

According to the invention there is provided a data communications network including a plurality of stationary access points and a plurality of mobile units, a mobile unit being capable of communicating with at least two access points in a predetermined range therefrom, comprising:

means in the mobile unit to scan for and associate

the mobile unit with the most eligible access point at predetermined intervals, the most eligible access point being selected according to each of the following criteria:

(a) received access point signal quality; and
(b) loading factor at the access point.

Accordingly, a simple and reliable arrangement is provided enabling preemptive roaming and optimum selection of an access point for association with a mobile unit.

Each mobile unit may select a group of eligible access points and select the most eligible access point from that group. The received access point signal quality may be represented by the received signal strength indication (RSSI). The loading factor may be defined by the number of mobile units associated with a given access point. The cellular communications network may comprise a 1Mbps frequency-hopping spread-spectrum wireless LAN conforming to the IEEE 802.11 draft specification.

Each mobile unit may send out a probe message packet to all access points wherein the probe packet has no destination address but a mobile unit specific source address. The probe packet may include an identification of the access point with which the mobile unit is currently associated. Each access point that detects the probe packet may send a probe response packet containing the following information:

access point address;
access point frequency hopping pattern;
access point present channel;
time remaining in present channel;
loading factor.

The mobile unit may carry out its selection on the basis of the signal quality of, and information contained in the received probe response packets or the access point signal quality may be determined from a beacon signal sent by the access point independently of a probe response packet.

Each mobile unit may store the RSSI value for each access point and calculate an average value over a predetermined period, and RSSI values outside a predetermined range may be omitted from the averaging calculation.

Each mobile unit may carry out a full scan of all available frequency channels on power-up and thereafter at regular intervals. The full scan may be carried out at approximately thirty second intervals. Each mobile unit may carry out a partial scan of known access points at regular intervals more frequently than a full scan is carried out, for example at approximately five second intervals.

Each mobile unit not associated with an access point may identify on scanning all access points with signal quality equal to or above a threshold value and select for association the access point having the lowest loading factor; when two or more access points have an equal lowest loading factor the access point having the highest RSSI value may be selected. The threshold value may be set at six counts below the highest detected RSSI value.

A mobile unit associated with an access point and experiencing an unacceptably low communication level may roam excluding the current access point from selection. The unacceptably low communication level may be achieved when more than 50% retries, CRC errors or missed beacons are experienced. The excluded access point may be re-included for selection when its RSSI value has increased by a predetermined limit. If no eligible access points are identified for re-association the mobile unit may continue to associate with the current access point.

A mobile unit associated with an access point and achieving a satisfactory level of communication may make a scanning decision at predetermined intervals. A satisfactory communication level may be achieved when 50% or less retries, CRC errors or missed beacons are experienced. An eligible group may be selected comprising all access points with signal quality above a predetermined threshold, the group including the current access point when its signal quality is above a further predetermined threshold, and the access point may be selected having the lowest loading factor; access points having a loading factor of more than a given proportion of the current access point loading factor may be excluded and where two or more access points have the same loading factor, the access point having the highest signal quality may be selected. The eligible group threshold value may be six counts below the highest received RSSI value, the current access point further threshold value may be eleven counts below that RSSI value, and access points having a loading factor of more than 75% of the current access point loading factor may be excluded.

Each mobile unit may carry out a partial scan of known access points at predetermined intervals and may carry out the roaming decision immediately after the partial scan.

The communications network may be included in one of an inventory, price verification, mark-down, portable point of sale, order entry, shipping, receiving and package tracking systems.

According to the invention there is further provided a mobile unit for use in a cellular communications network comprising a plurality of access points, the mobile unit including a communications system for association with an access point and a selection system for scanning all access points, selecting a group of eligible access points for association and selecting from that group a most eligible access point, selection being carried out according to the following criteria:

a received access point signal quality; and
loading factor.

According to the invention there is further provided a cellular communications network comprising a plurality of mobile units and a plurality of access points, the mobile unit being arranged to roam and associate with a selected access point, the mobile unit including a selection system for selecting a group of eligible access points for association and selecting from that group the most eligible access point, selection being carried out according to the following criteria:

received access point signal quality; and
loading factor.

According to the invention there is further provided a method of operation of a cellular communications network, the network including a plurality of access points in communication with each other and a plurality of mobile units wherein:

each mobile unit scans for and associates with the most eligible access point at predetermined intervals, each mobile unit selecting a group of eligible access points and, from that group, selecting the most eligible access point according to the following criteria:
received access point signal quality; and
loading factor.

According to the invention there is yet further provided a data communications network including a plurality of stationary access points and a plurality of mobile units wherein:

each mobile unit scans for and selects as eligible access point for association therewith on the basis of received access point signal quality and loading factor at the access point and wherein:
a physical area is defined within which all mobile units must be kept and access points are provided adjacent the or each exit point from the physical area.

The access point at the exit point may include a directional (horn) antenna providing a strong signal in the vicinity of the exit point.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment, when read in conjunction with the accompanying drawings. It is to be understood that the invention may be carried into practice in a number of ways, and the described embodiment is not intended to be limiting.

BRIEF DESCRIPTION OF THE DRAWING(S)

Fig. 1 is a schematic illustration showing the communication system of the present invention in operation;
Fig. 2a is a block diagram illustrating the steps carried out by a mobile unit during the roaming process;
Fig. 2b is a flow chart illustrating the steps carried out by a mobile unit for selection of the most eligible access point;
Fig. 3 shows a probe response message typically sent by an access point according to the present invention; and
Fig. 4 is a schematic illustration showing a further embodiment of the communication system of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Fig. 1 one application of a cellular wireless communication system is in the field of inventorying. One or more operators 1 each carry a mobile unit 2, such as a portable computer. Information concerning the items 3 to be inventoried is entered into the mobile unit 2, for example by scanning bar code symbols on the items 3. In order to communicate the information obtained to a backbone house computer 4 a plurality of access points 5 are provided each connected to the house computer 4 and one to another, each access point 5 together with the backbone house computer 4 forming a cell. Depending on the location of the operator 1 it is desirable that the mobile unit should select the optimum access point; in addition, if conditions change, for example if the operator 1 changes position, it is desirable that the mobile unit 2 should, if necessary, reassociate with a new access point if the current access point 5 does not allow a satisfactory performance or the new access point offers an improved performance. The mobile unit 2 and access points 5 are arranged for wireless communication at radio frequencies, for example, 2.4GHz in the industrial scientific medical (ISM) band. The steps carried out by a mobile unit 2 which is not currently associated to an access point in selecting an access point are shown in Figs. 2a and 2b. As shown in the block diagram of Fig. 2a the mobile unit (MU) firstly sends out a probe packet (6) to all access points (AP). The probe packet contains the mobile unit source address but has no destination address and hence any access point that detects the probe packet must send a response. Accordingly, the probe packet is detected by all access points within range (7) and each of those access points sends out a probe response packet (8).

The form of the probe response packet is shown in Fig. 3. The information contained therein includes the access point address, the hopping pattern, the present channel, time left in the present channel, the loading factor (discussed in more detail below) and any other

timing information that may be required. Returning to Fig. 2a the mobile unit associates with the most eligible access point based on the probe response packets that it receives.

Referring to Fig. 2b the mobile unit selects the most eligible access point in the following manner:

As each probe packet response (PPR) is received (10) the signal quality of the response is measured by determining the received signal strength indication (RSSI) (11). For reference, RSSI values generally vary from 25 to 60, with good communications experienced above approximately 35. In practice, rather than relying on a single instantaneous value, the RSSI information for each access point is placed in a table in the memory of the mobile unit and is updated each time a probe response packet is received from that access point. In order to minimise fluctuation the RSSI value for each access point in the table is averaged over a predetermined number of responses. It has been found that large variations in the RSSI values for a given access point have been recorded even when measured by a stationary mobile unit, varying by as much as 15 counts over one minute, and in order to reduce the range of values and minimise "slow thrashing" (when "thrashing", a mobile unit associates with a first access point, then roams to a second access point after a short period of time and then further access points in a random manner without any long attachment to a single access point and "slow thrashing" may be interpreted accordingly) the averaging calculation may include the step of discarding values outside a given range, for example ten or more counts below the average RSSI value.

Once the RSSI values have been calculated, an "eligible group" of access points is selected (12), including all access points having an RSSI value no more than six counts below the best detected RSSI value. From that group the access point having the lowest load factor (LF) is determined (13,14). The load factor is a measure of how many mobile units are currently associated with a given access point; in the present case the load factor is represented by a simple numerical value representing the exact number of associated mobile units. The access point thus selected is the most eligible access point and the mobile unit then selects that access point for association. If more than one access points within the eligible group exhibit the same load factor then, of those, the access point having the highest RSSI value is selected as the most eligible access point and the mobile unit associates with that access point.

The mobile units are programmed to carry out an update probe at predetermined intervals. In the present embodiment each mobile unit carries out a full scan, probing all seventy nine channels, upon power up and every thirty seconds. Full scans last approximately 100ms. In addition partial scans, covering known access points, are performed every five seconds. The probe response packet transmitted by an access point contains all necessary synchronisation information for a mobile unit to latch on to the current channel of the access point and follow the hopping pattern at any stage. In an alternative arrangement the RSSI value for the access point is calculated not from the strength of the probe response signal but from the strength of the "beacon packet" issued by the access point. Each access point issues a beacon packet every 100 milliseconds containing, in addition to other information, timing information similar to that contained in the probe response packet.

A slightly different approach is taken where a mobile unit is currently associated with an access point but at a communication level that is unsatisfactory. An unsatisfactory communication level may be identified, for example, when more than fifty per cent retries, cyclic redundancy code (CRC) errors or missed beacons are detected. In that case the mobile unit will re-associate using the steps illustrated in Figs. 2a and 2b except that the access point with which the mobile unit was experiencing poor communications will be excluded from the eligible group of access points (see step (12) of Fig. 2b). The in-eligible access point can, however, in due course be re-admitted to the eligible group after a succession of acceptable RSSI values have been observed. It should be noted that a mobile unit experiencing poor communication will re-associate only if an eligible access point is identified.

In cases where a mobile unit is not experiencing an unsatisfactory communications level (as defined above) it makes a roaming decision every five seconds after a partial scan. Once again the steps described above with reference to Fig. 2b are carried out, but with the following modifications:

1. The current access point is included in the eligible group if its RSSI value is no more than eleven counts below the best RSSI value.
2. When choosing the access point having the lowest loading factor in the group, access points having a loading factor which is more than 75% of the loading factor of the current access point loading factor are excluded.

The additional steps enable the mobile unit to avoid "frivolous roaming" that is to say, re-association with new access points when the current access point is in fact satisfactory.

The system thus allows preemptive roaming providing for dynamic load balancing, that is, a mobile unit may re-associate with a new access point although it is not experiencing poor communications with a current access point, but the newer access point will offer considerably improved communications. The possibility of a mobile unit losing contact with an access point altogether and experiencing periods where it is not communicating with any access points, may thus be avoided.

In addition, the system has been improved by adjusting the sensitivity so that a mobile unit will not tend to roam from a current associated access point to

another at the rate that it would otherwise, where the signal strengths of various access points are similar in magnitude. Accordingly, greater stability is achieved.

In a further modification the probe packet may include an identification of the access point that the mobile unit is currently associated with for example, the BSS ID. Such an arrangement would be more reliable than the messages passed between access points relaying re-association events.

A further embodiment of the invention is shown in Fig. 4. In some cases it may be desirable to provide information concerning the physical location of a mobile unit. For example the information may be provided to a system administrator 20 who may take action based on the information. Alternatively the house computer 4 may take action automatically on the basis of certain information.

For example, mobile units are often used in stock exchanges by traders for receiving orders and executing trades, as it is illegal to execute trades outside the building. In order, therefore, to determine whether a mobile unit is being removed from the building, access points 5 are provided adjacent each exit door 21. Each access point 5 is equipped with a directional (horn) antenna 22 designed to provide a strong signal over a narrow pattern in the vicinity of and covering the whole of the doorway. According to the roaming operation of the mobile units discussed above, any mobile unit will associate with an access point having high signal quality and which is lightly loaded and hence any mobile unit passing an access point 5 over an exit door 21 (when a mobile unit is being taken through the door) will associate with that access point. Once the system has detected that a mobile unit has associated with an access point over an exit door 21 the necessary steps can be taken by a house computer. For example an alert can be sounded which may in addition disable operation of the mobile unit. It is, of course, possible to identify which exit door the mobile unit was being taken through by identifying the physical location of the associated access point.

In the embodiment shown in Fig. 4 a cellular communications network is in use in a self-checkout retail system where wireless mobile units are provided to customers for the purpose of scanning their own purchases, for example, using bar code symbols. In that case an access point 5 provided over an exit 21 could be used to alert the store management 20 that a scanner was leaving the premises and to sound an alarm at the door.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generical or specific aspects of this invention and, therefore, such adaptions should and are intended to be comprehended without the meaning and range of equivalence of the following claims.

According to its broadest aspect the invention relates to:

A data communications network including a plurality of stationary access points and a plurality of mobile units, a mobile unit being capable of communicating with at least two access points in a predetermined range therefrom, comprising:
means in the mobile unit to scan for and associate the mobile unit with the most eligible access point at predetermined intervals.

A mobile unit for use in a communications network comprising a plurality of access points, the mobile unit including a communications system for association with an access point and a selection system for scanning all access points

A cellular communications network comprising a plurality of units and a plurality of access points, the unit being arranged to roam and associate with a selected access point, the mobile unit including a selection system.

A method of operation of a cellular communications network, the network including a plurality of access points in communication with each other and a plurality of mobile units wherein the following step is provided:

selecting the most eligible access point according to the following criteria:
received access point signal quality; and
loading factor.

A data communications network including a plurality of stationary access points and a plurality of mobile units wherein:

each mobile unit scans for and selects a most eligible access point for association therewith on the basis of received access point signal quality.

It should be noted that the objects and advantages of the invention may be attained by means of any compatible combination(s) particularly pointed out in the items of the following summary of the invention and the appended claims.

SUMMARY OF THE INVENTION:

1. A data communications network including a plurality of stationary access points and a plurality of mobile units, a mobile unit being capable of communicating with at least two access points in a predetermined range therefrom, comprising:

means in the mobile unit to scan for and associate the mobile unit with the most eligible access point at predetermined intervals, the most eligible access point being selected according to each of the following criteria:

(a) received access point signal quality; and

(b) loading factor at the access point.

2. A network in which each mobile unit selects a group of eligible access points and selects the most eligible access point from that group.

3. A network in which the received access point signal quality is represented by the received signal strength indication (RSSI).

4. A network in which the loading factor is defined by the number of mobile units associated with a given access point.

5. A network in which the cellular communications network comprises a 1Mbps frequency-hopping spread-spectrum wireless LAN conforming to the IEEE 802.11 draft specification.

6. A network in which each mobile unit sends out a probe message packet to all access points wherein the probe packet has no destination address but a mobile unit specific source address.

7. A network wherein the probe packet includes an identification of the access point with which the mobile unit is currently associated.

8. A network in which each access point that detects the probe packet sends a probe response packet containing the following information:

access point address;
access point frequency hopping pattern;
access point present channel;
time remaining in present channel;
loading factor.

9. A network in which the mobile unit carries out its selection on the basis of the signal quality of, and information contained in the received probe response packets.

10. A network in which the access point signal quality is determined from a beacon signal sent by the access point independently of a probe response packet.

11. A network in which each mobile unit stores the RSSI value for each access point and calculates an average value over a predetermined period.

12. A network in which RSSI values outside a predetermined range are omitted from the averaging calculation.

13. A network in which each mobile unit carries out a full scan of all available frequency channels on power-up and thereafter at regular intervals.

14. A network in which the full scan is carried out at approximately thirty second intervals.

15. A network in which each mobile unit carries out a partial scan of known access points at regular intervals more frequently than a full scan is carried out.

16. A network in which the mobile unit carries out a partial scan at approximately five second intervals.

17. A network in which each mobile unit not associated with an access point identifies on scanning all access points with signal quality equal to or above a threshold value and selects for association the access point having the lowest loading factor and in which when two or more access points have an equal lowest loading factor the access point having the highest RSSI value is selected.

18. A network in which the threshold value is set at six counts below the highest detected RSSI value.

19. A network in which a mobile unit associated with an access point and experiencing an unacceptably low communication level roams and excludes the current access point from selection.

20. A network wherein the unacceptably low communication level is achieved when more than 50% retries, CRC errors or missed beacons are experienced.

21. A network in which the excluded access point is re-included for selection when its RSSI value exceeds a predetermined limit.

22. A network in which, if no eligible access points are identified for re-association the mobile unit continues to associate with the current access point.

23. A network in which a mobile unit associated with an access point and achieving a satisfactory level of communication makes a scanning decision at predetermined intervals.

24. A network in which a satisfactory communication level is achieved when 50% or less retries, CRC errors or missed beacons are experienced.

25. A network in which an eligible group is selected comprising all access points with signal quality above a predetermined threshold, the group including the current access point when its signal quality is above a further predetermined threshold, and the access point is selected having the lowest loading

factor, wherein access points having a loading factor of more than a given proportion of the current access point loading factor are excluded and wherein, where two or more access points have the same loading factor the access point having the highest signal quality is selected.

26. A network in which the eligible group threshold value is six counts below the highest received RSSI value, the current access point further threshold value is eleven counts below that RSSI value, and in which access points having a loading factor of more than 75% of the current access point loading factor are excluded.

27. A network in which each mobile unit carries out a partial scan of known access points at predetermined intervals and carries out the roaming decision immediately after the partial scan.

28. A network in which the communications network is included in one of an inventory, price verification, mark-down, portable point of sale, order entry, shipping, receiving and package tracking systems.

29. A mobile unit for use in a cellular communications network comprising a plurality of access points, the mobile unit including a communications system for association with an access point and a selection system for scanning all access points, selecting a group of eligible access points for association and selecting from that group a most eligible access point, selection being carried out according to the following criteria:

a received access point signal quality; and
loading factor.

30. A cellular communications network comprising a plurality of mobile units and a plurality of access points, the mobile unit being arranged to roam and associate with a selected access point, the mobile unit including a selection system for selecting a group of eligible access points for association and selecting from that group the most eligible access point, selection being carried out according to the following criteria:

received access point signal quality; and
loading factor.

31. A method of operation of a cellular communications network, the network including a plurality of access points in communication with each other and a plurality of mobile units wherein:

each mobile unit scans for and associates with the most eligible access point at predetermined intervals, each mobile unit selecting a group of eligible access points and, from that group, selecting the most eligible access point according to the following criteria:

received access point signal quality; and
loading factor.

32. A data communications network including a plurality of stationary access points and a plurality of mobile units wherein:

each mobile unit scans for and selects a most eligible access point for association therewith on the basis of received access point signal quality and loading factor at the access point and wherein:
a physical area is defined within which all mobile units must be kept and access points are provided adjacent the or each exit point from the physical area.

33. A network in which the or each access point at the respective exit point includes a directional (horn) antenna providing a strong signal in the vicinity of the exit point.

Claims

1. A data communications network including a plurality of stationary access points and a plurality of mobile units, a mobile unit being capable of communicating with at least two access points in a predetermined range therefrom, comprising:

means in the mobile unit to scan for and associate the mobile unit with the most eligible access point at predetermined intervals, the most eligible access point being selected according to each of the following criteria:

(a) received access point signal quality; and
(b) loading factor at the access point.

2. A network as claimed in claim 1 in which each mobile unit selects a group of eligible access points and selects the most eligible access point from that group.

3. A network as claimed in claim 1 in which the received access point signal quality is represented by the received signal strength indication (RSSI).

4. A network as claimed in claim 1 in which the loading factor is defined by the number of mobile units associated with a given access point.

5. A network as claimed in claim 1 in which preferably the cellular communications network comprises a

1Mbps frequency-hopping spread-spectrum wireless LAN conforming to the IEEE 802.11 draft specification,

in which preferably each mobile unit sends out a probe message packet to all access points wherein the probe packet has no destination address but a mobile unit specific source address,

wherein preferably the probe packet includes an identification of the access point with which the mobile unit is currently associated,

in which preferably each access point that detects the probe packet sends a probe response packet containing the following information:

access point address;
access point frequency hopping pattern;
access point present channel;
time remaining in present channel;
loading factor,

in which preferably the mobile unit carries out its selection on the basis of the signal quality of, and information contained in the received probe response packets,

in which preferably the access point signal quality is determined from a beacon signal sent by the access point independently of a probe response packet,

in which preferably each mobile unit stores the RSSI value for each access point and calculates an average value over a predetermined period,

in which preferably RSSI values outside a predetermined range are omitted from the averaging calculation,

in which preferably each mobile unit carries out a full scan of all available frequency channels on power-up and thereafter at regular intervals,

in which preferably the full scan is carried out at approximately thirty second intervals,

in which preferably each mobile unit carries out a partial scan of known access points at regular intervals more frequently than a full scan is carried out,

in which preferably the mobile unit carries out a partial scan at approximately five second intervals,

in which preferably each mobile unit not associated with an access point identifies on scanning all access points with signal quality equal to or above a threshold value and selects for association the access point having the lowest loading factor and in which when two or more access points have an equal lowest loading factor the access point having the highest RSSI value is selected,

in which preferably the threshold value is set at six counts below the highest detected RSSI value,

in which preferably a mobile unit associated with an access point and experiencing an unacceptably low communication level roams and excludes the current access point from selection,

wherein preferably the unacceptably low communication level is achieved when more than 50% retries, CRC errors or missed beacons are experienced,

in which preferably the excluded access point is re-included for selection when its RSSI value exceeds a predetermined limit,

in which preferably, if no eligible access points are identified for re-association the mobile unit continues to associate with the current access point,

in which preferably a mobile unit associated with an access point and achieving a satisfactory level of communication makes a scanning decision at predetermined intervals,

in which preferably a satisfactory communication level is achieved when 50% or less retries, CRC errors or missed beacons are experienced,

in which preferably an eligible group is selected comprising all access points with signal quality above a predetermined threshold, the group including the current access point when its signal quality is above a further predetermined threshold, and the access point is selected having the lowest loading factor, wherein access points having a loading factor of more than a given proportion of the current access point loading factor are excluded and wherein, where two or more access points have the same loading factor the access point having the highest signal quality is selected,

in which preferably the eligible group threshold

value is six counts below the highest received RSSI value, the current access point further threshold value is eleven counts below that RSSI value, and in which access points having a loading factor of more than 75% of the current access point loading factor are excluded,

in which preferably each mobile unit carries out a partial scan of known access points at predetermined intervals and carries out the roaming decision immediately after the partial scan, and

in which preferably the communications network is included in one of an inventory, price verification, mark-down, portable point of sale, order entry, shipping, receiving and package tracking systems.

6. A mobile unit for use in a cellular communications network comprising a plurality of access points, the mobile unit including a communications system for association with an access point and a selection system for scanning all access points, selecting a group of eligible access points for association and selecting from that group a most eligible access point, selection being carried out according to the following criteria:

a received access point signal quality; and
loading factor.

7. A cellular communications network comprising a plurality of mobile units and a plurality of access points, the mobile unit being arranged to roam and associate with a selected access point, the mobile unit including a selection system for selecting a group of eligible access points for association and selecting from that group the most eligible access point, selection being carried out according to the following criteria:

received access point signal quality; and
loading factor.

8. A method of operation of a cellular communications network, the network including a plurality of access points in communication with each other and a plurality of mobile units wherein:

each mobile unit scans for and associates with the most eligible access point at predetermined intervals, each mobile unit selecting a group of eligible access points and, from that group, selecting the most eligible access point according to the following criteria:
received access point signal quality; and
loading factor.

9. A data communications network including a plurality of stationary access points and a plurality of mobile units wherein:

each mobile unit scans for and selects a most eligible access point for association therewith on the basis of received access point signal quality and loading factor at the access point and wherein:
a physical area is defined within which all mobile units must be kept and access points are provided adjacent the or each exit point from the physical area,

wherein preferably each access point at the respective exit point includes a directional (horn) antenna providing a strong signal in the vicinity of the exit point.

10. A data communications network including a plurality of stationary access points and a plurality of mobile units, a mobile unit being capable of communicating with at least two access points in a predetermined range therefrom, comprising:

means in the mobile unit to scan for and associate the mobile unit with the most eligible access point at predetermined intervals.

11. A mobile unit for use in a communications network comprising a plurality of access points, the mobile unit including a communications system for association with an access point and a selection system for scanning all access points

12. A cellular communications network comprising a plurality of units and a plurality of access points, the unit being arranged to roam and associate with a selected access point, the mobile unit including a selection system,

13. A method of operation of a cellular communications network, the network including a plurality of access points in communication with each other and a plurality of mobile units wherein the following step is provided:

selecting the most eligible access point according to the following criteria:
received access point signal quality; and
loading factor.

14. A data communications network including a plurality of stationary access points and a plurality of mobile units wherein:

each mobile unit scans for and selects a most eligible access point for association therewith on the basis of received access point signal quality.

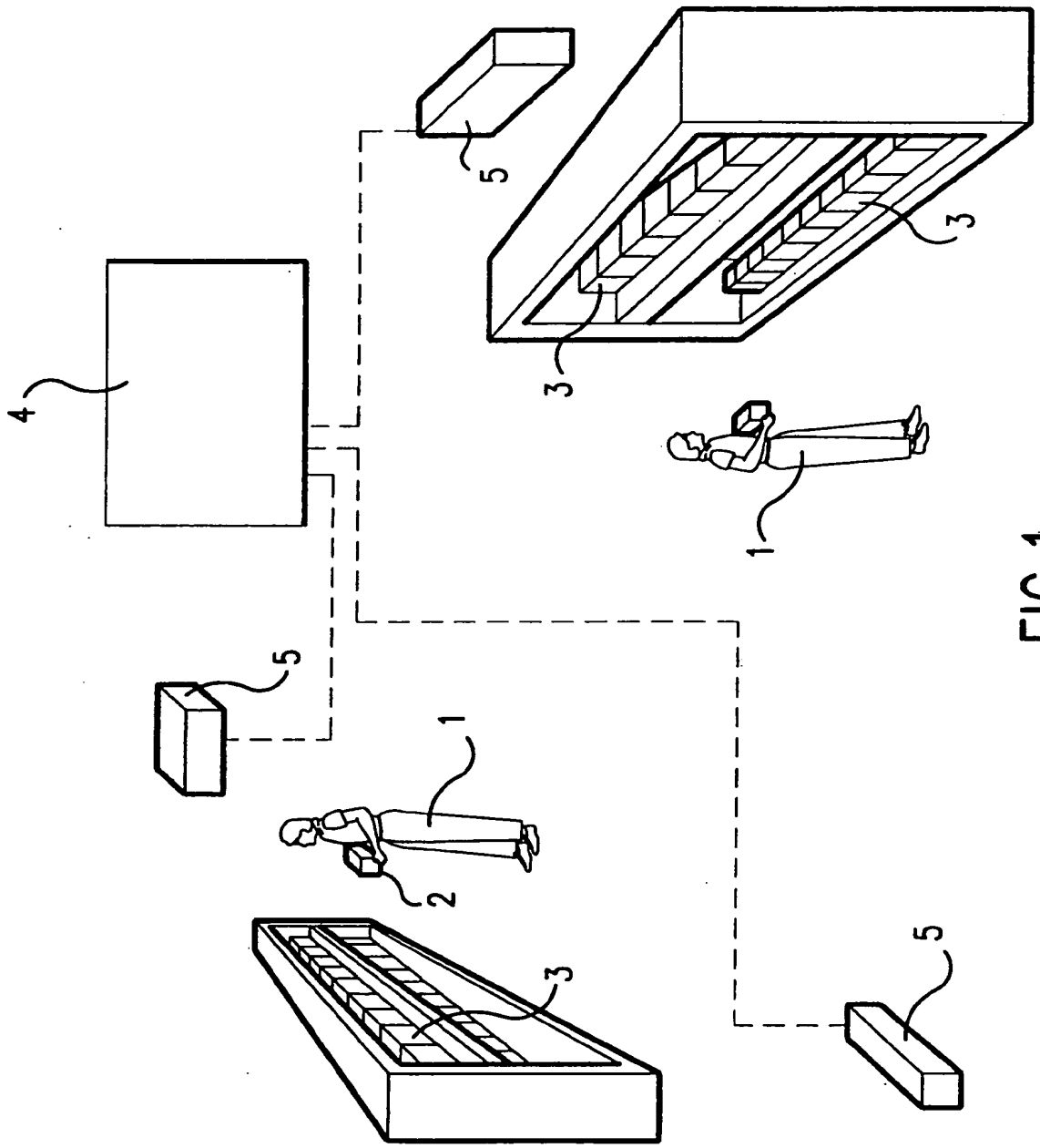

FIG.1

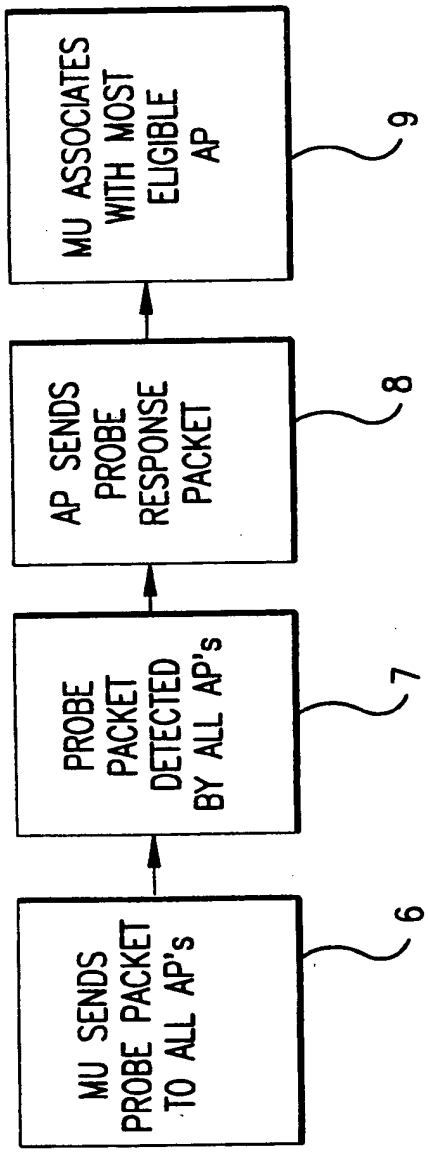
MU SENDS PROBE PACKET TO ALL AP's
6
PROBE PACKET DETECTED BY ALL AP's
7
AP SENDS PROBE RESPONSE PACKET
8
MU ASSOCIATES WITH MOST ELIGIBLE AP
9

FIG.2a

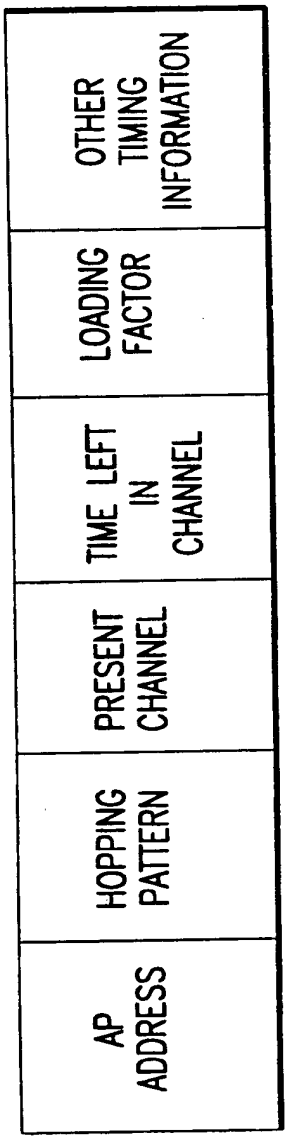
AP ADDRESS
HOPPING PATTERN
PRESENT CHANNEL
TIME LEFT IN CHANNEL
LOADING FACTOR
OTHER TIMING INFORMATION

FIG.3

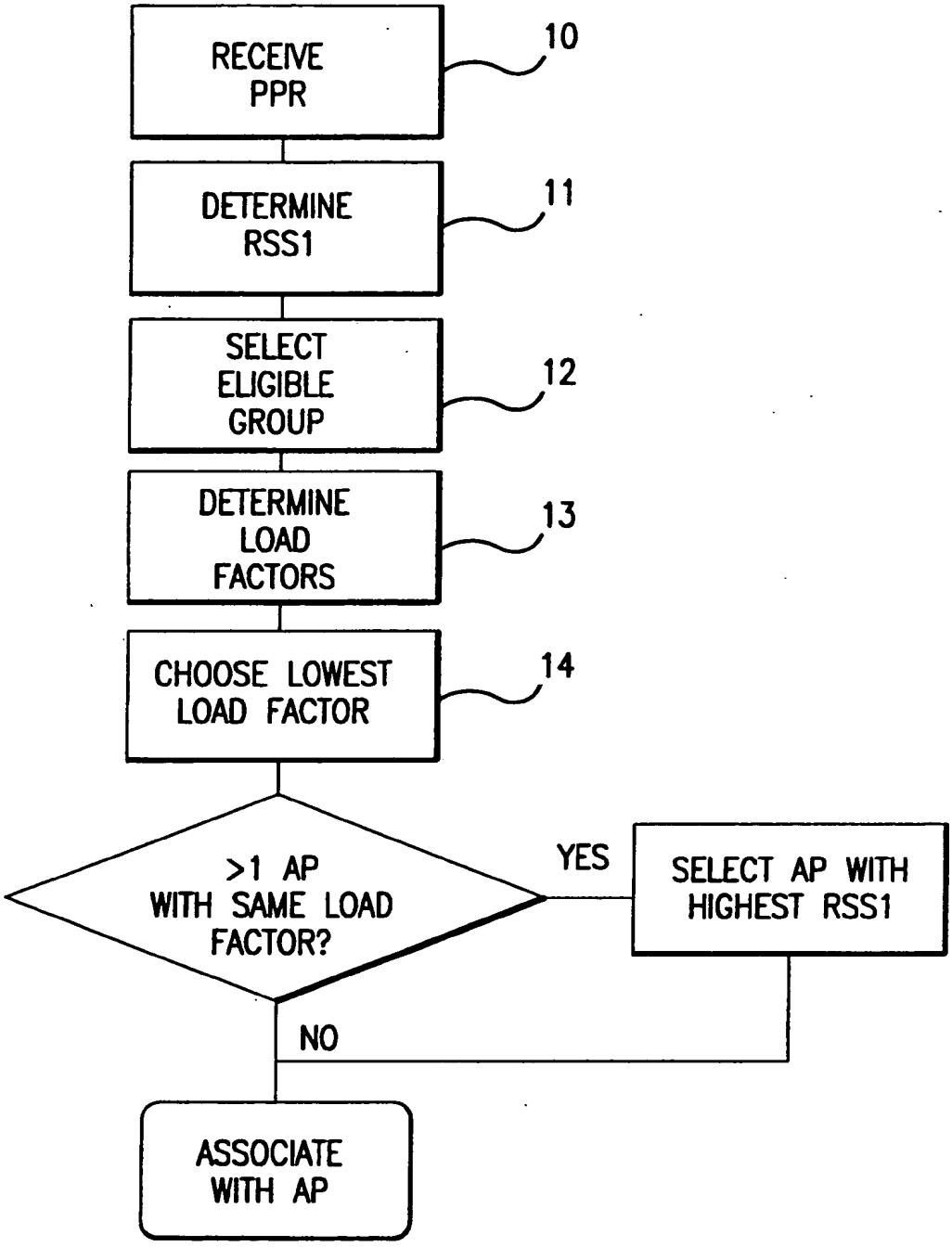
RECEIVE PPR
10
DETERMINE RSS1
11
SELECT ELIGIBLE GROUP
12
DETERMINE LOAD FACTORS
13
CHOOSE LOWEST LOAD FACTOR
14
>1 AP WITH SAME LOAD FACTOR?
YES
SELECT AP WITH HIGHEST RSS1
NO
ASSOCIATE WITH AP

FIG.2b

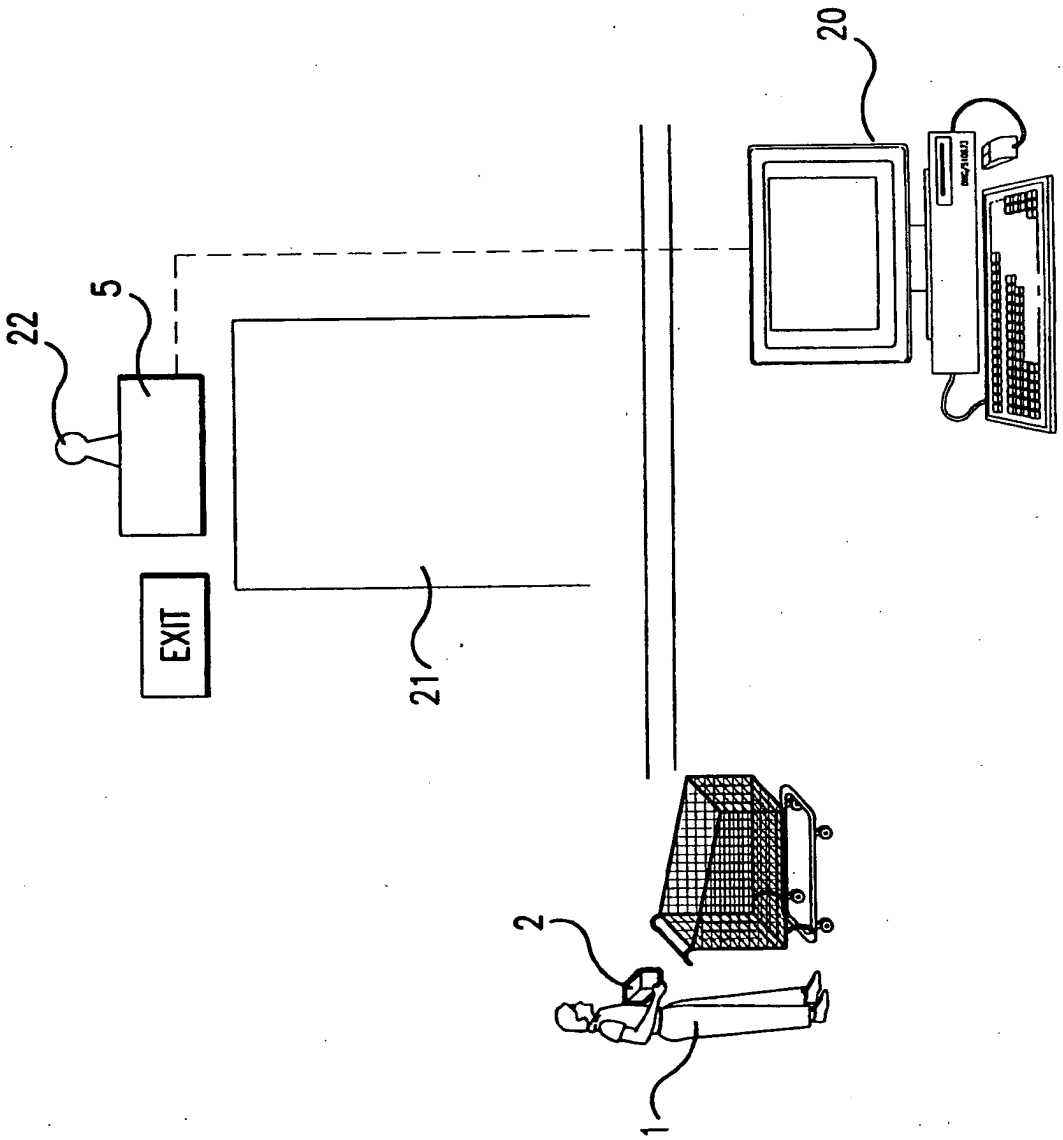

FIG.4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 7282

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP-A-0 483 544 (INTERNATIONAL BUSINESS MACHINES CORPORATION) 6 May 1992 * column 1, line 1 - column 2, line 14 * * column 4, line 27 - column 5, line 26 * * column 9, line 4 - column 10, line 26 * * column 11, line 10 - column 12, line 24 * ---	1-4,6-8, 10-14	H04L12/28
Y		9	
A		5	
X	US-A-5 448 569 (INTERNATIONAL BUSINESS MACHINES CORPORATION) 5 September 1995 * column 1, line 54 - line 68 * * column 2, line 34 - line 43 * * column 3, line 37 - line 56 * * column 4, line 17 - line 60 * * column 5, line 6 - line 62 * * column 6, line 24 - line 60 * * column 7, line 35 - line 52 * * column 9, line 59 - column 10, line 24 * * column 11, line 13 - line 52 * ---	1-4,6-8, 10-14	
A		5,9	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
X	EP-A-0 268 375 (NORTHERN TELECOM LIMITED) 25 May 1988 * column 2, line 25 - line 37 * * column 4, line 2 - line 48 * * column 11, line 56 - column 12, line 9 * * column 12, line 40 - line 47 * ---	1,3,4, 10-14	H04L H04Q H04M
A		2,5-9	
	-/--		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30 January 1997	Vaskimo, K

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 7282

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	EP-A-0 578 374 (NORTHERN TELECOM LIMITED) 12 January 1994 * page 3, line 3 - line 24 * * page 3, line 42 - line 44 * * page 4, line 7 - line 14 * * page 4, line 35 - line 46 * * page 5, line 1 - line 15 * * page 6, line 5 - page 7, line 54 * * figure 2B *	9	
A	WO-A-93 01663 (MOTOROLA, INC.) 21 January 1993 * page 1, line 15 - page 2, line 11 * * page 5, line 26 - page 6, line 18 *	1-3,5-14	
A	ICL TECHNICAL JOURNAL, vol. 8, no. 2, November 1992, OXFORD, GB, pages 272-283, XP000320461 EDWIN TURNER: "Communications Technology for the Retail Environment" * the whole document *		TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30 January 1997	Vaskimo, K

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D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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